SINGLE-BEAM BATHYMETRIC DATA NEAR SAINT MICHAEL, ALASKA, COLLECTED JULY 8–9, 2022

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Raw Data File 2023-8

M2Ocean Hydroball sensor towed behind a boat near Saint Michael, Alaska, on July 8, 2022. Photo: Alaska Division of Geological & Geophysical Surveys.

This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

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DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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SINGLE-BEAM BATHYMETRIC DATA NEAR SAINT MICHAEL, ALASKA, COLLECTED JULY 8–9, 2022

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data near Saint Michael, Alaska, on July 8 and 9, 2022 (fig. 1). The purpose of this survey is to provide bathymetric data for the assessment of coastal hazards and riverine erosion studies. These data were collected using an M2Ocean Hydroball integrated bathymetric sensor and processed using CIDCO DepthStar software. Coincident Global Navigation Satellite System (GNSS) base station and water level time series data were collected using Trimble survey equipment and Solinst Levelogger pressure and temperature sensors, respectively, to correct horizontal and vertical positions. This data product does not meet the International Hydrographic Organization (IHO) bathymetric coverage standard (IHO, 2022), is not intended to determine navigability, and is released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31006.

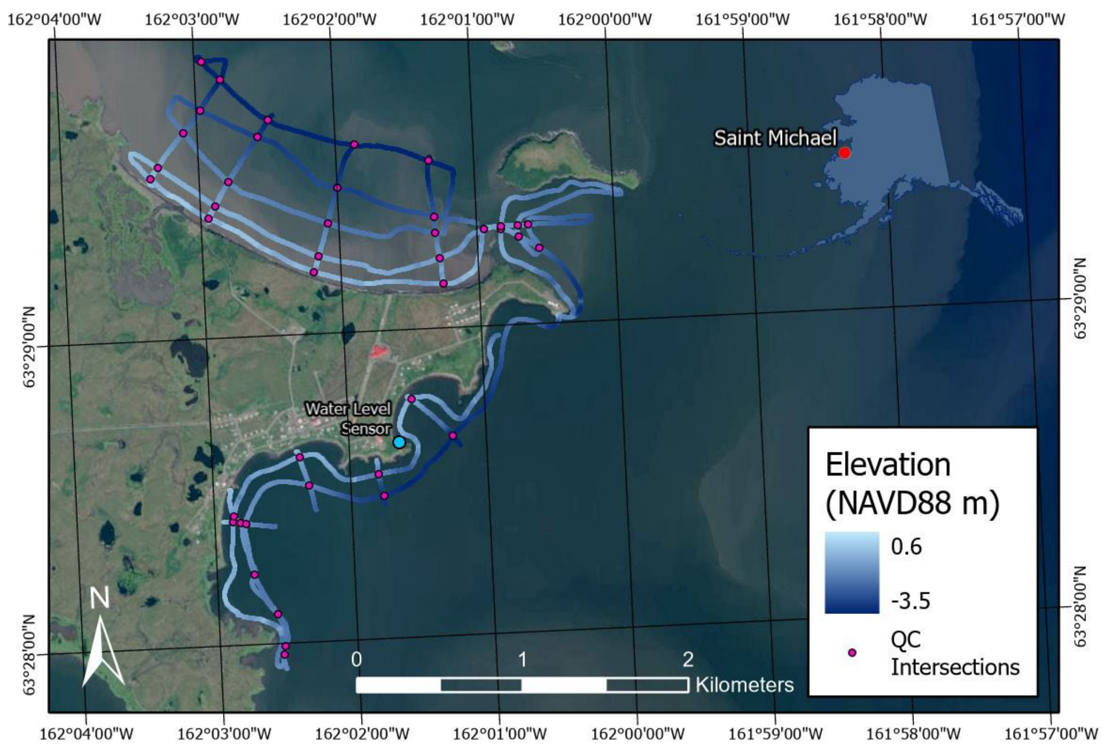

Figure 1. Map of bathymetric soundings near Saint Michael, Alaska.

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LIST OF DELIVERABLES

- Bathymetric sounding data
- Data dictionary
- Metadata

METHODS

Field Collection

DGGS used an M2Ocean Hydroball bathymetric sensor composed of an Imagenex 852 single-beam echosounder (SBES), a Tallysman TW3972 GNSS antenna, and a Honeywell HMR3000 inclinometer to collect field data. On July 8 and 9, 2022, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over a temporary benchmark. Base station data were used to correct the HydroBall sensor positions. To provide water level corrections, DGGS collected derived water level time series data from two temporarily installed Solinst model 3001 Levelogger Edge LT M10/F30 pressure and temperature sensors, one fully submerged approximately 18 m offshore (fig. 2) in a sheltered bay east of Saint Michael and the other placed in a dry, shaded location on land.

Figure 2. Solinst Levelogger installation offshore near Saint Michael, Alaska.

Survey Details

The bathymetric survey was performed on July 8 and 9, 2022, from 8:15 AM to 11:50 AM and 8:15 AM to 11:05 AM AKDT, respectively. The weather throughout the survey was clear, with little to no wind and calm waters. The Hydroball was attached to a catamaran configuration and towed behind a small boat equipped with an outboard motor at speeds below 4 knots. The Imagenex 852 SBES was configured with a maximum range of 20 m, gain of 5 dB, and pulse length of 120 microseconds. Due to time and vessel constraints, the bathymetric survey was performed using a survey pattern inconsistent with the requirements outlined in the IHO standards (IHO, 2022). Approximately 29.8 km of near-shore marine bathymetry were surveyed.

Data Processing

Base positions were corrected using Online Positioning User Service (OPUS) solutions, which were used to update the Hydroball sensor positions using post-processed kinematic (PPK) adjustments from RTKLIB version 2.4.2 software with the following settings applied: L1+L2 frequencies forward and backward filtered; a 10-degree elevation mask; broadcast ionosphere and Saastamoinen troposphere corrections; a minimum fixed ambiguity ratio of 3; and L1/L2 code/carrier-phase error ratios of 100. During post-processing, DGGS applied International GNSS Service (IGS) precise orbits and final clock solutions retrieved from the Crustal Dynamics Data Information System (CDDIS) available from urs.earthdata.nasa.gov/. Final corrected data were exported as time-stamped position files in the WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS collected temperature-compensated pressure–time series data from July 8 at 7:03 AM on July 8 to 1:59 PM AKDT July 9, 2022, at synchronized 5-minute intervals on the two Levelogger sensors. Using a barometric (millibar) to water column equivalent (meter) conversion of 1.0 mb = 0.0101972 m, DGGS converted both the submerged Levelogger and the dry air Levelogger data. Subtracting the dry air pressures in the water column equivalent from the submerged water column equivalent pressures provides the barometrically compensated water level. These data were then adjusted to the vertical datum NAVD88 (GEOID12B) elevation of the submerged sensor location, converted to Coordinated Universal Time (UTC), sampled to the hour to reduce excess noise due to water turbulence, and interpolated to the second using a 4-degree Lagrange interpolating polynomial,

$$z = \sum_{j}^{4} f_j(t)\,, \qquad f_j(t) = z_j \prod_{\substack{k=1 \\ k\neq j}}^{4} \frac{t - t_k}{t_j - t_k}$$

where z_j is the observed water level elevation, t_j is the observation time, t_k represents the other three primary times used in the calculation, and z is the interpolated water level elevation at time t (fig. 3).

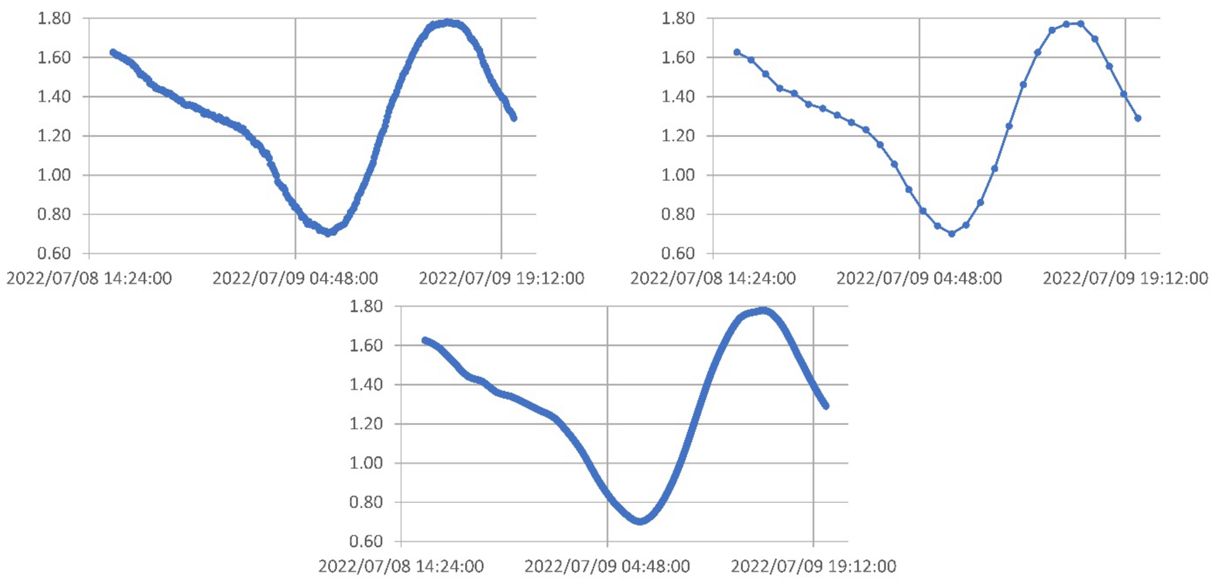

Figure 3. Comparison of 5-minute (top-left), per hour (top-right), and per second (bottom) water level elevation data throughout the survey.

Using CIDCO DepthStar software, DGGS imported the Hydroball device file containing raw GNSS position, SBES depth, and inclinometer gyrocompass data. These data were corrected to the 0.115 m catamaran draft and 0.364 m GNSS antenna reference point offset from the SBES acoustic center. These data were then georeferenced to the corrected PPK positions and interpolated water level time series using the water level reference survey (WLRS) sounding reduction method, applying a sound velocity correction of 1500 m/s (saltwater default value) to all data. The final soundings were exported with WGS84 horizontal coordinates and

NAVD88 (GEOID12B) elevations. These data were projected to the horizontal coordinate system NAD83 (2011) UTM Zone 3 North using Esri ArcGIS Pro version 3.0.2 software.

Data Formatting

All data were delivered in comma-delimited (CSV) format with column headers and accompanied by a data dictionary detailing the header names, definitions, and applicable units.

Coordinate System and Datum

All data were processed in the horizontal coordinate system WGS84 and vertical datum NAVD88 (GEOID12B). All data were delivered in the horizontal coordinate system NAD83 (2011) UTM Zone 3 North and vertical datum NAVD88 (GEOID12B).

ACCURACY REPORT

Using the IHO minimum bathymetric standards (IHO, 2022) would be inappropriate for assessing these data, which do not meet the IHO-prescribed systematic survey pattern criteria. DGGS has developed order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards to avoid misinterpretation. The reported accuracy of these data is intended to express quality only and should not be considered sufficient for safe navigation.

Horizontal Accuracy

We quantified the horizontal accuracy of the GNSS position data using the latitudinal and longitudinal peak-to-peak errors provided by OPUS (table 1). Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have latitudinal and longitudinal errors less than or equal to 0.04 m.

We quantified the horizontal accuracy of individual depth soundings using the maximum manufacturer-reported angular accuracy of the Honeywell HMR3000 inclinometer, 0.6 degrees. DGGS applied the following formula to determine the horizontal accuracy for each depth sounding,

$$\pm\Delta(d) = d \tan 0.6°$$

where $\pm\Delta$ is the horizontal uncertainty, and d is the sounding depth at a given location.

We categorized the quality of depth sounding data by order of accuracy based on the maximum Total Horizontal Uncertainty (THU) derived from the following formula (IHO, 2022),

$$THU_{max} = \min_{i \in [1,n]} (a + bd_i)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient that represents the portion of uncertainty that varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 2-dimensional (position) 95 percent confidence level of 0.027 m.

Vertical Accuracy

We quantified the vertical accuracy of the GNSS position data using the combined ellipsoidal height peak-to-peak errors provided by OPUS and ortho height RMS error provided by NOAA's Vertical Datum Transformation software. Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have vertical errors less than or equal to 0.08 m.

We quantified the vertical accuracy of individual depth soundings using the manufacturer-reported range resolution, 0.02 m, as a percentage of the maximum range, 50.00m, of the Imagenex 852 single-beam echosounder. DGGS applied the following formula to determine the vertical accuracy for each depth sounding,

$$\pm\Delta(d) = \frac{0.02}{50.00}d$$

where $\pm\Delta$ is the vertical uncertainty and d is the sounding depth at a given location.

We categorized the quality of depth sounding data by order of accuracy based on the maximum Total Vertical Uncertainty (TVU) derived from the following formula (IHO, 2022),

$$TVU_{max} = \min_{i \in [1,n]}\left(\sqrt{a^2 + (bd_i)^2}\right)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient that represents the portion of uncertainty that varies with varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.001 m.

Overall Accuracy

We quantified the overall accuracy of the bathymetric data using the vertical separation of overlapping point-to-point 3-dimensional lines within the data. These data intersected 42 times in total, with a separation range between 0.005 m and 0.121 m, average separation of 0.045 m, and median separation of 0.035 m (fig. 4). Overall vertical error is calculated as the root-mean-square (RMS) error of the offsets at these intersection points, with a total vertical error of 0.029 m (table 2). These data meet DGGS 1st Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.058 m.

Data Consistency and Completeness

DGGS filtered out low-quality, non-differential (single) GNSS position data using standard categorization (single, float, fixed). All 0.0 m depth soundings, excessive noise, and vertical anomalies were removed through visual inspection. DGGS used time series data for depth and attitude (pitch and yaw) to manually remove anomalous soundings and any sounding reporting an attitude deviation larger than twenty degrees. No significant erroneous areas requiring repair were identified during this quality control process.

Base station data were processed using the OPUS static processing service, which derives GNSS coordinates from the average of three independent, single-baseline solutions, each computed by double-differenced carrier-phase measurements from three nearby National Continuously Operating Reference Stations

(CORS). OPUS provides the range of the three individual single baselines, known as the peak-to-peak error. These ranges include any errors from the CORS used during processing (NOAA, 2022).

OPUS ortho height ranges are estimated using the same calculations applied to horizontal error reporting, typically resulting in a much larger potential error compared to the peak-to-peak error of the ellipsoid height. For more accurate ortho height error reporting, DGGS used NOAA's Vertical Datum Transformation software for final elevation conversions from NAD83 (2011) ellipsoidal heights to NAVD88 (GEOID12B) ortho heights. This software employs accurate, multi-parameter mathematical equations and location-specific grid models to perform vertical transformations and report the total root-mean-square error (NOAA, 2016).

Table 1. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
647364.062	7042625.528	25.616	0.005	0.006	0.068

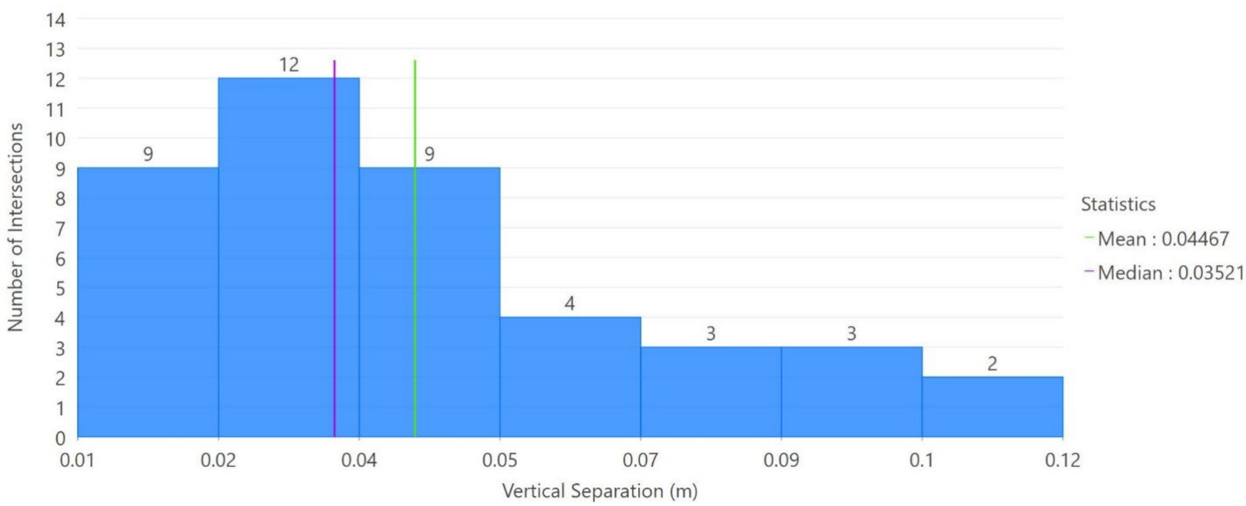

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 2. Survey intersection locations and vertical separations.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
647077.4452	7041757.3209	0.005
647200.5854	7041408.6871	0.006
646614.0312	7043861.9845	0.006
648147.3120	7042467.6139	0.007
647470.6598	7042118.3439	0.010
648292.3434	7043470.5259	0.015
646879.8736	7044505.1755	0.015
646961.3831	7043631.8475	0.019
648284.9860	7043570.2368	0.021

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
647383.4705	7040922.4503	0.022
647282.2451	7044150.2169	0.023
647042.6492	7043775.1709	0.024
648792.2603	7043451.4944	0.026
647642.1840	7043529.8363	0.027
647147.3339	7041714.0112	0.028
648398.0520	7042244.9000	0.028
648319.0034	7043318.6588	0.029
646772.2879	7044074.5674	0.029
648787.6766	7043518.2364	0.030
648248.1548	7043905.8982	0.031
648688.3629	7043513.6049	0.031
647114.3238	7041717.7414	0.040
647697.0956	7043741.7740	0.045
648851.2125	7043519.7136	0.049
646570.5800	7043794.2633	0.049
648582.7850	7043492.4621	0.050
646871.3391	7044209.8708	0.051
647217.0479	7044048.8878	0.051
648917.9473	7043379.6774	0.051
647588.4195	7043330.0289	0.052
646993.2297	7044392.9957	0.062
647950.2054	7042014.5154	0.064
648686.3466	7043496.5642	0.069
647799.9875	7044001.6415	0.071
647980.6550	7041880.9114	0.073
647530.0547	7041948.1749	0.073
647389.4986	7040975.0325	0.084
647342.8470	7041166.8320	0.090
647560.9202	7043236.0376	0.092
648341.1045	7043162.6911	0.102
646925.6206	7043556.1588	0.106
647072.1614	7041722.2522	0.121
	Mean	**0.045**
	Median	**0.035**
	Standard Deviation	**0.030**
	95% Confidence Level	**0.058**

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
	Root-Mean-Square Error	**0.029**

Table 3. DGGS order of accuracy criteria.

Criteria	4th Order	3rd Order	2nd Order	1st Order
THU	$a = 20\ m$ $b = 0.10$	$a = 5\ m$ $b = 0.05$	$a = 2\ m$ $b = 0.00$	$a = 1\ m$ $b = 0.00$
TVU	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.085 m**	**5.042 m**	**2.000 m**	**1.000 m**
$\boldsymbol{TVU_{max}}$	**1.000 m**	**0.500 m**	**0.250 m**	**0.150 m**

ACKNOWLEDGMENTS

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REFERENCES

International Hydrographic Organization, 2022, Standards for hydrographic surveys (S-44), Edition 6.1.0, 51 p.

National Oceanic and Atmospheric Administration, 2016, Estimation of vertical uncertainties in VDatum, retrieved from https://vdatum.noaa.gov/docs/est_uncertainties.html.

National Oceanic and Atmospheric Administration, 2022, About OPUS, retrieved from https://geodesy.noaa.gov/OPUS/about.jsp.